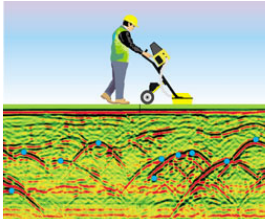
Introduction to geophysical methods:

Techniques and targets



Reference:
Sharma p1-10
Reynolds p1-27

What do we mean by applied geophysics?

Remote sensing

Constraining the Earth's sub-surface with observations at the surface

Geophysical techniques measure physical phenomena:

- Gravity
- Magnetism
- Elastic waves
- Electricity
- Electromagnetic waves

Which are sensitive to sub-surface physical properties:

- Density
- Magnetic susceptibility
- Seismic wave velocity and density
- Resistivity
- Conductance / inductance / permitivity

Oh, and it's relatively cheap

Active and passive

Passive

Measure naturally occurring phenomena

- Gravity field
- Magnetic field
- Seismic arrivals - earthquakes

Active

Transmit a signal into the subsurface and record what comes back

- Seismic arrival – explosions
- Electrical current
- Electromagnetic waves

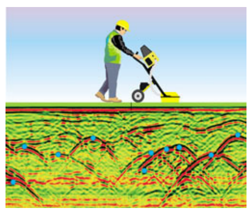
think **scale**

Our scale

...meters to kilometers

The techniques we'll talk about are used in the fields of

- **Environmental geophysics**
- **Engineering geophysics**
- **Exploration geophysics**



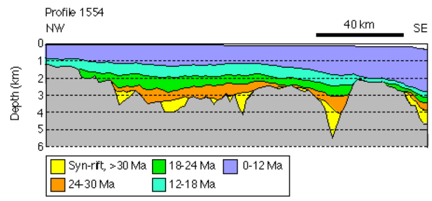
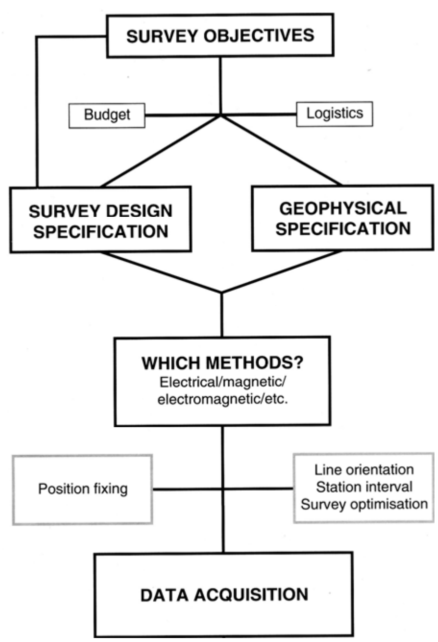


Figure 4. Interpreted seismic profile from the Pearl River Mouth Basin of the South China Sea showing the thick Neogene sequences that provenance data indicate were eroded from the South China Block.

Planning a survey



Target identification

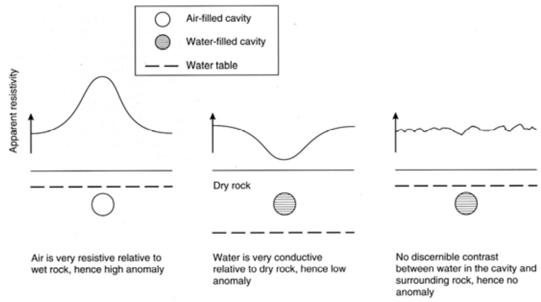
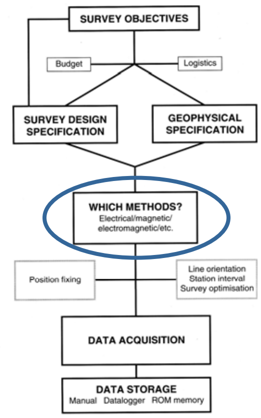


Figure 1.5 Contrasts in physical properties from different geological targets give rise to a geophysical target. When there is no contrast, the target is undetectable geophysically



Examples

Magnetics

Main use: locating steel drums and pipes

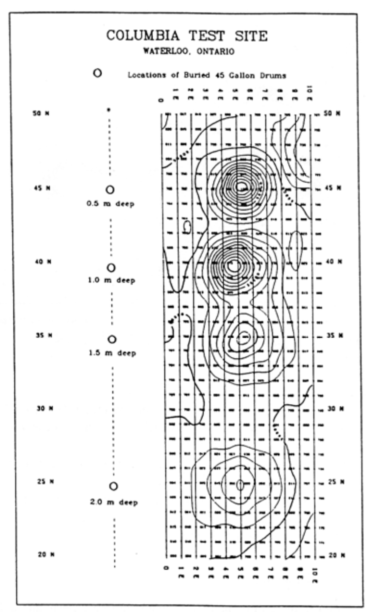
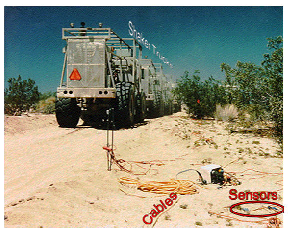


Fig. 3.27 Contour map showing ΔT anomalies caused by four buried steel drums. Maximum amplitudes of the anomalies vary from over 200 nT for the drum at 0.5 m depth to about 70 nT for that at 2 m depth. Instrument used, OMNI Proton Magnetometer. (Courtesy H. O. Seigel and Scintrex.)

Examples

Seismic reflection



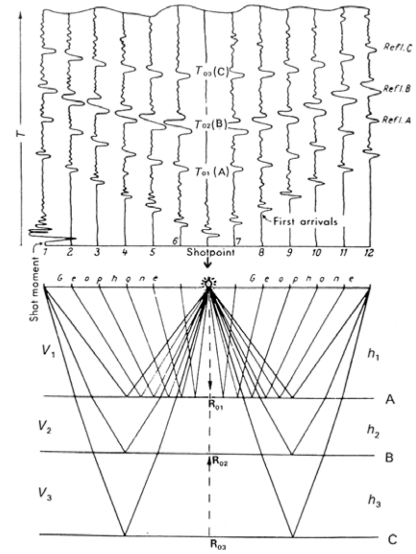


Fig. 4.14 Schematic diagram showing the production of a reflection seismogram. The 12-trace record shows the time sequence of the reflected pulses from reflecting horizons, A, B, and C. T_{01}, T_{02}, and T_{03} are the two-way vertical travel-times from points R_{01}, R_{02}, and R_{03}, respectively, below the shotpoint. The significance of first arrivals is discussed in Section 4.4.5.

Examples

Seismic reflection

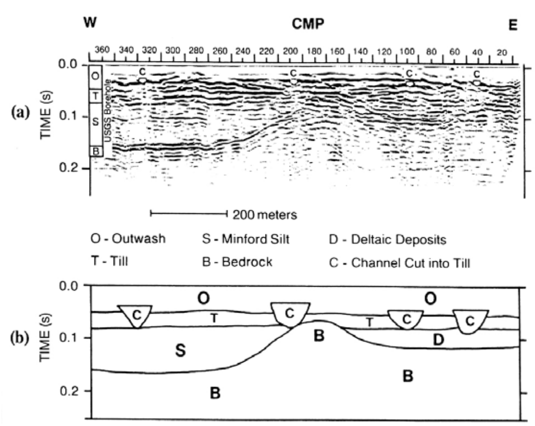
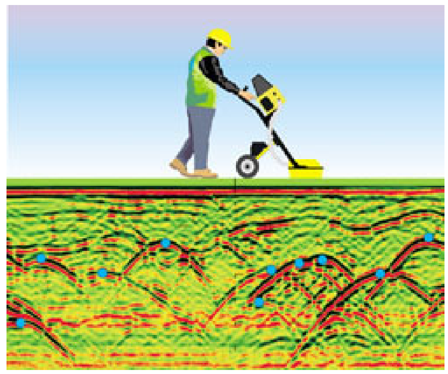


Fig. 4.31 (a) Six-fold CMP reflection section below the survey line at Cedar Bog, Ohio, U.S.A. The USGS test hole intersected the bedrock (shale with thin beds of limestone) at a depth of 158 m. (b) Interpreted geological section showing the configuration of the glacial material filling parts of the two valleys separated by a bedrock high. (After Wolfe and Richard, 1990.)

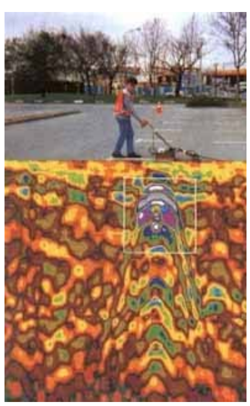
Examples

Ground penetrating radar



Examples

Ground penetrating radar



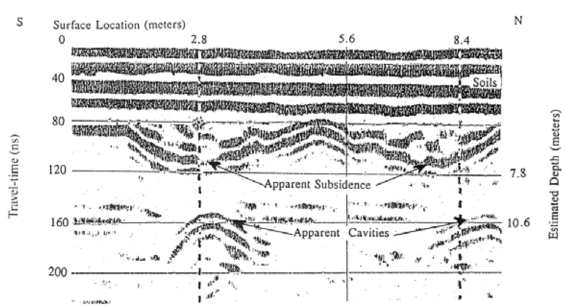


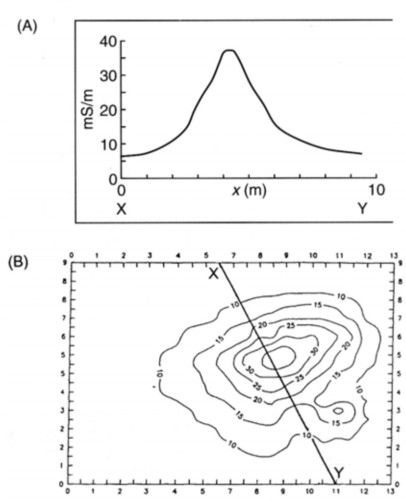
Fig. 8.10 Ground-penetrating radar profile across Highway 6, near Eureka, Juab County, Utah, U.S.A. Note the hyperbolic diffraction patterns at about 160 ns; these are interpreted to be due to cavities in the subsurface. Dipole antenna, frequency 100 MHz. (After Benson, 1995.)

Techniques and targets

Geophysical Method	Dependent physical property	Hydrocarbon exploration (coal, oil, gas)	Regional geologic study (>100s km2)	Exploration/development of mineral deposits	Engineering site investigations	Hydrogeological investigations	Detection of subsurface cavities	Mapping leachate and contamination plumes	Location of buried metallic objects	Archaeogeophysics	Forensic geophysics
Gravity	Density	**P**	**P**	s	s	s	s			s	
Magnetic	Susceptibility	**P**	**P**	**P**	s		m		**P**	**P**	
Seismic refraction	Elastic moduli, density	**P**	**P**	m	**P**	s	s				
Seismic reflection	Elastic moduli, density	**P**	**P**	m	s	s	m				
Resistivity	Resistivity	m	m	**P**	**P**	**P**	**P**	**P**	s	**P**	m
Spontaneous potential	Potential differences			**P**	m	**P**	m	m	m		
Induced polarization	Resistivity, capacitance	m	m	**P**	m	s	m	m	m	m	m
Electromagnetic (EM)	Conductance, inductance	s	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	m
EM - VLF	Conductance, inductance	m	m	**P**	m	s	s	s	m	m	
EM – Ground penetrating radar	Permitivity, conductivity			m	**P**	**P**	**P**	s	**P**	**P**	**P**
Magneto-telluric	Resistivity	s	**P**	**P**	m	m					

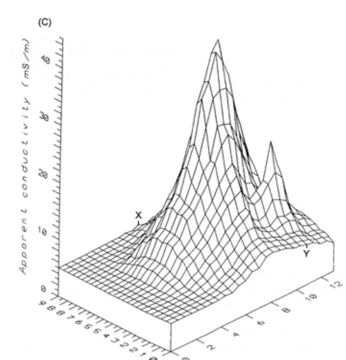
P – primary method; s – secondary; m – maybe sometimes

Profiling vs. mapping



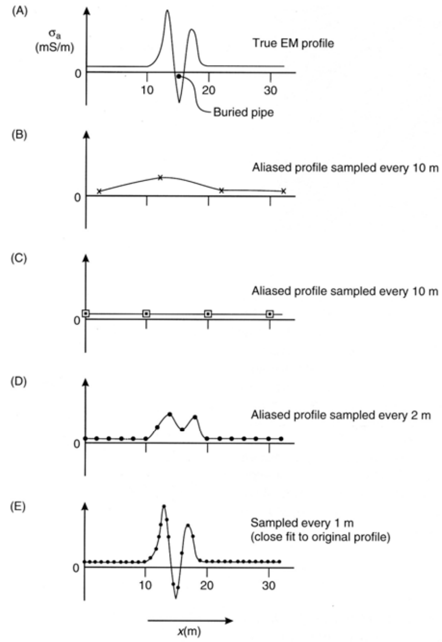
What is the nature of the target?

- **2D or 3D?**
- **Preliminary site evaluation necessary?**



Station spacing

Must ensure that spacing is sufficient to sample anticipated signal



Limitations

- **Methods require contrast in physical properties**
- **Nonuniqueness**

  Direct modeling: calculate the result of a specific structure

  Inverse modeling: determine the causative structure from observations – usually ambiguous

  e.g. small shallow body vs. large deep body
- **Resolution is determined by the wavelength of the signal**

  sesimic: km, radar: cm
- **Noise prevents recovery of low amplitude signal**

  e.g. wind, traffic, water pumps, power lines

Multiple methods

...to improve uniqueness and cross-check interpretations

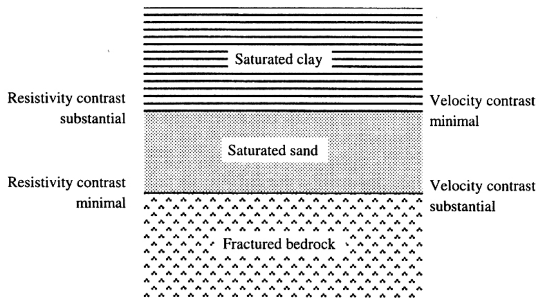


Figure 1-1 Determining the thickness of a confined aquifer by using both seismic refraction and electrical resistivity.

Introductions

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Sources

Course webpage: http://www.geology.wisc.edu/courses/g594/

- lecture notes, homeworks etc

Required text

Environmental and Engineering Geophysics, 1st ed, Sharma, 1997

Other reference texts

An Introduction to Applied and Environmental Geophysics, Reynolds, 1997.

Applied Geophysics, 2nd ed, Telford, Geldart, Sheriff, 1990

Exploration geophysics of the shallow subsurface, Burger, 1992.

Whole Earth Geophysics, Lillie, 1999.

An introduction to geophysical exploration, Keary, Brooks and Hill, 2002

Grading

50% - Homework:	Bi-weekly problem sets
10% - Quiz 1	October 7th
15% - Quiz 2	November 23rd
25% - Final	December 17th 12:25pm

Announcements of any changes will be made at the lectures and on the webpage.

Topic schedule

Weeks 1-2:	Gravity Methods
Weeks 3-4:	Magnetic Methods
Weeks 5-6:	Resistivity Methods
Weeks 7-11:	Seismic Reflection and Refraction Methods
Weeks 11-13:	Electromagnetic Methods
Week 14:	Ground Penetrating Radar Methods
Week 15:	Borehole Methods

Additional material

Summaries and examples of other methods

Examples

Gravity

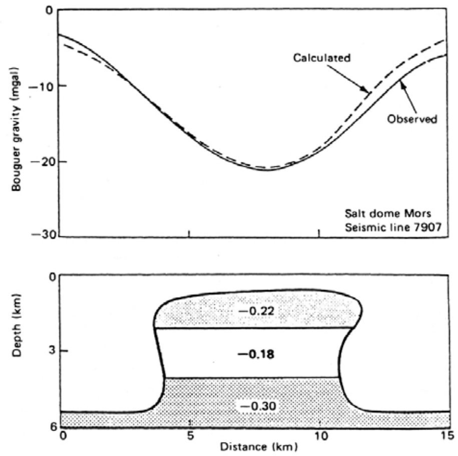


Fig. 2.21 Structural model of the Mors salt dome derived from the seismic section of Fig. 2.20 and the gravity profile. Density contrasts are based on a salt density of 2.17 g/cm³ (2170 kg/m³) and densities for off-dome sedimentary sections derived from seismic velocities. (After LaFehr, 1981.)

Examples

Seismic refraction

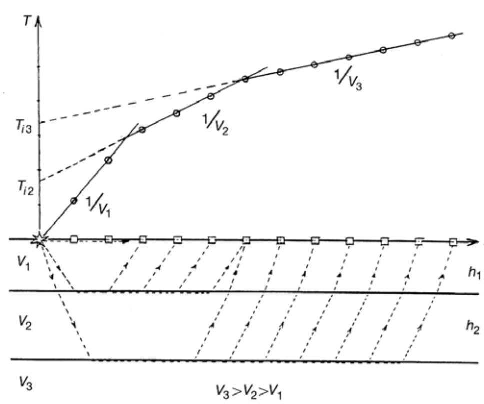


Fig. 4.35 Ray paths, travel-time–distance curves, and intercept times (T_i) for a three-layer structure with horizontal interfaces.

Examples

Electrical resistivity

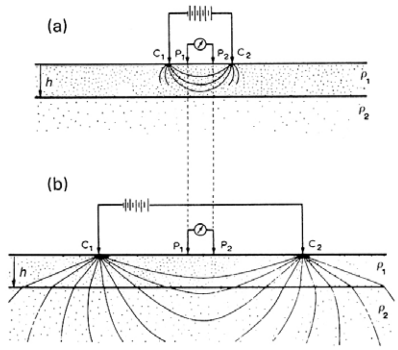
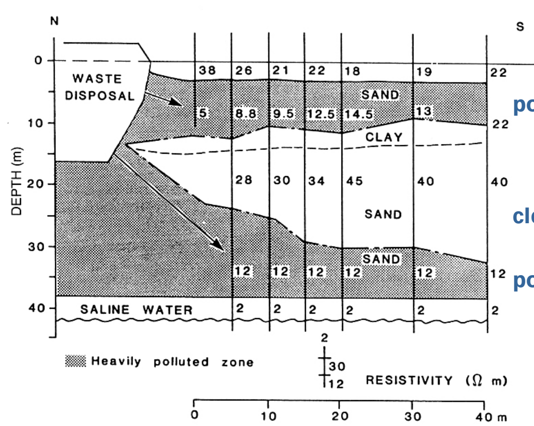


Fig. 6.9 Principle of electric sounding. (a) For small current electrode separation the current is virtually confined to the surface layer (resistivity ρ_1) and the measurement of p.d. between P_1 and P_2 gives information about ρ_1. (b) As the separation C_1C_2 increases a greater fraction of the current penetrates deeper into the substratum (resistivity ρ_2) and the measurements give more information about ρ_2.

Examples

Electrical resistivity



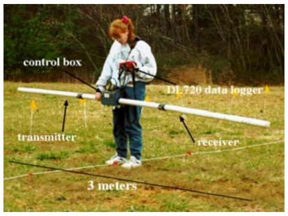
polluted sand

clean sand

polluted sand

Fig. 6.26 Interpreted geological section based on resistivity soundings in an area adjacent to a waste-disposal site near Utrecht, the Netherlands. (After Ritsema, 1984.)

Examples
Electromagnetic surveying



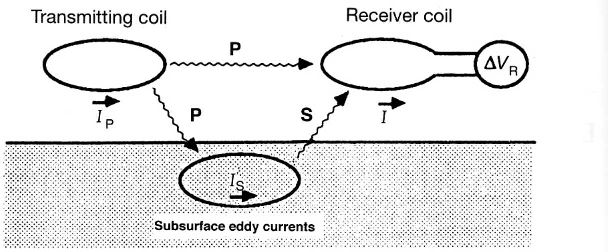


Fig. 7.1 A generalized sketch of an electromagnetic induction prospecting system. The transmitting coil, energized with an alternating current (I_P), produces a primary field which induces eddy currents (I_S) in the subsurface conductor. The receiver coil measures the resultant (**R**) of the primary field (**P**) and the secondary field (**S**) induced by the eddy currents.

Examples
Electromagnetic surveying

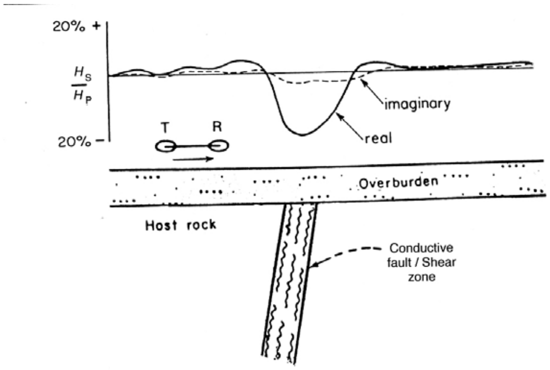


Fig. 7.7 Typical Slingram response over a vertical conductive target. In-phase (real) and quadrature (imaginary) components of the secondary field (H_S) are expressed as a percentage of the primary field, H_P. T and R denote, respectively, the transmitter and receiver coils of the mobile outfit.